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(54) **METHODS AND DEVICES FOR RADIO FREQUENCY (RF) MITIGATION PROXIMATE THE EAR**

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A61F 2/18 (2006.01)

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(Continued)

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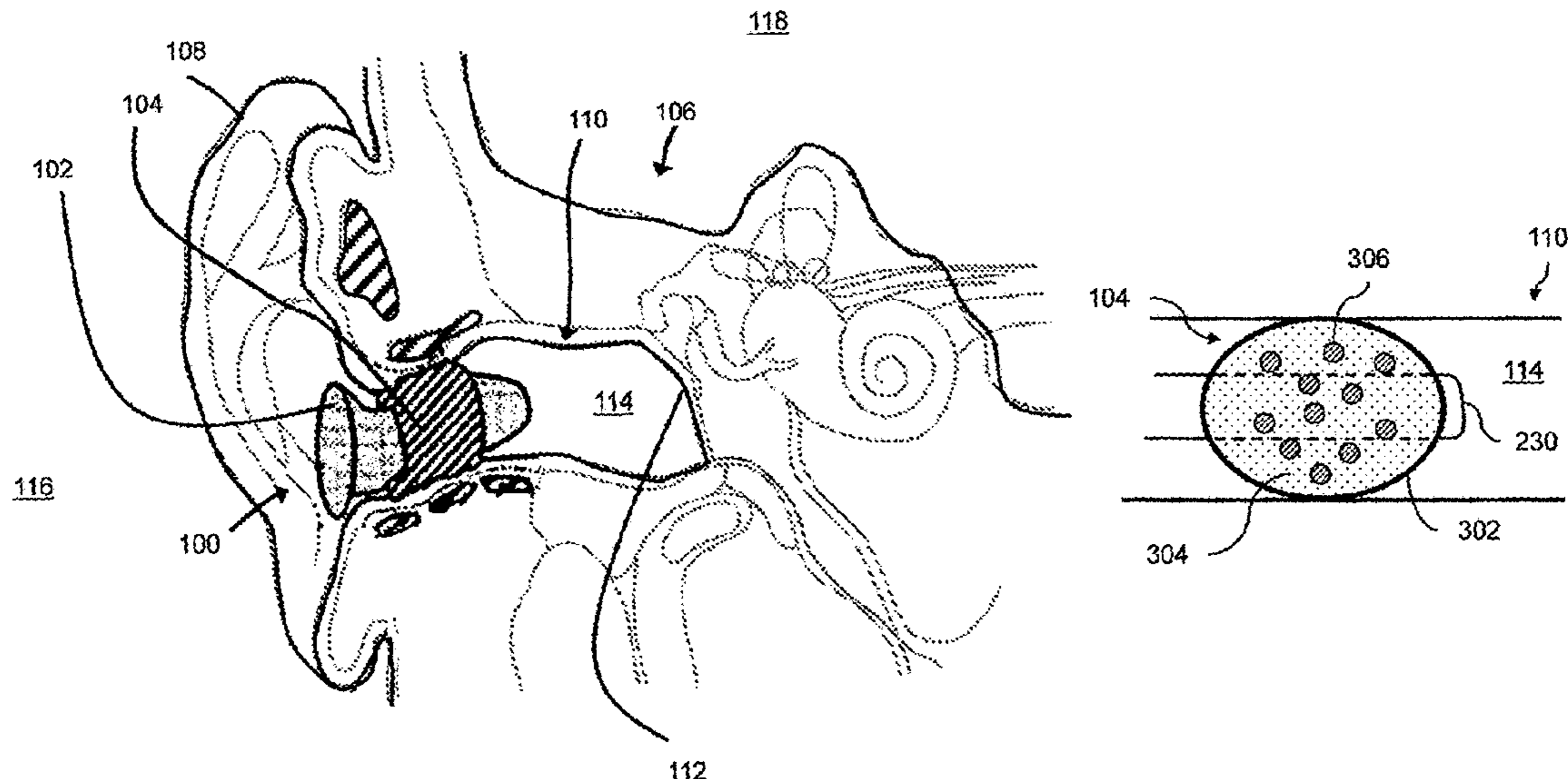
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(57) **ABSTRACT**

Earpieces and methods of forming earpieces for radio frequency (RF) mitigation are provided. An earpiece is configured to be inserted in an ear canal. The earpiece includes an insertion element and a sealing section disposed on the insertion element and configured to conform to the ear canal. The sealing section is configured to substantially mitigate radio frequency (RF) transmission and to substantially isolate the ear canal from an ambient environment.

20 Claims, 4 Drawing Sheets



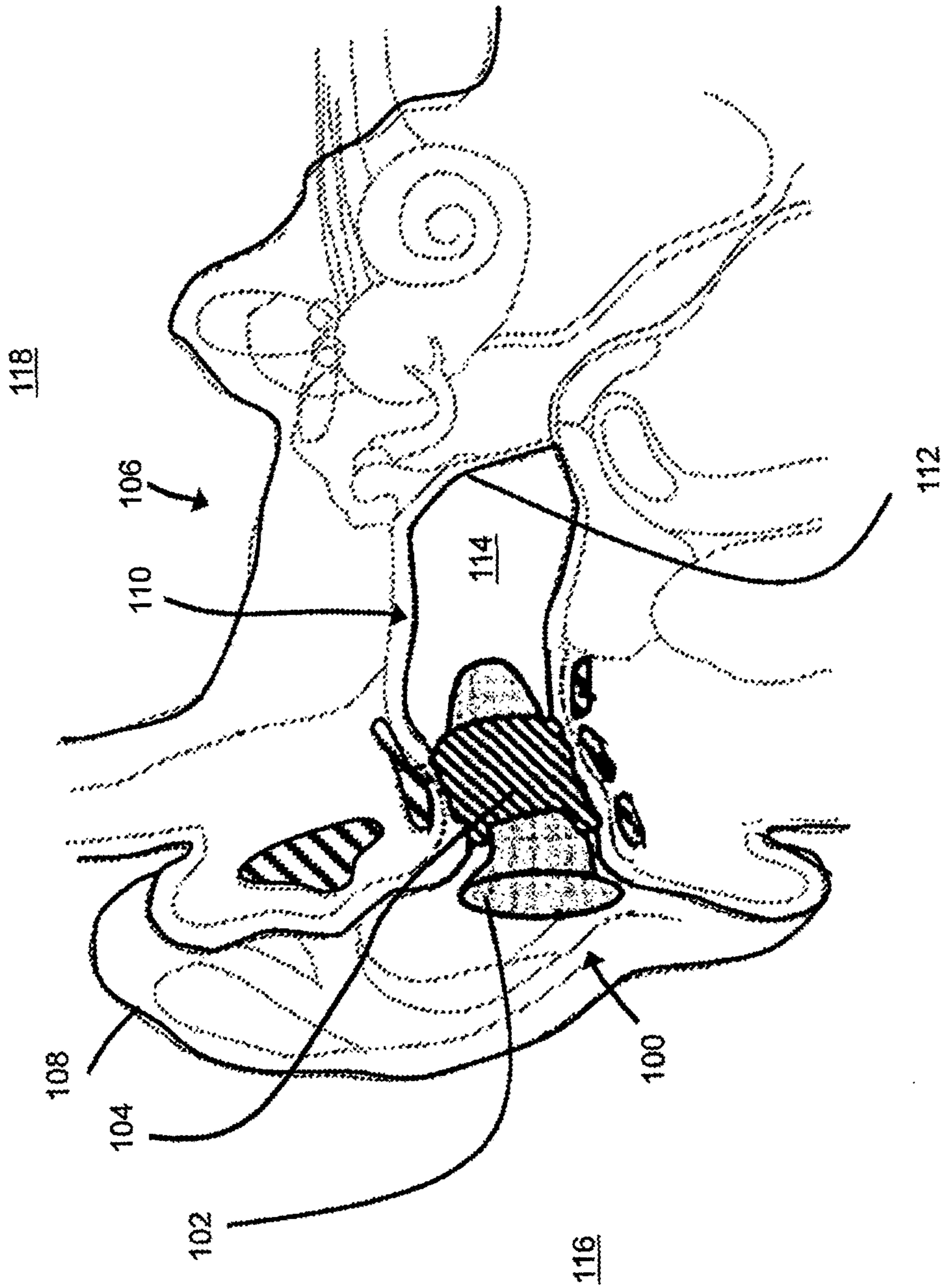


FIG. 1

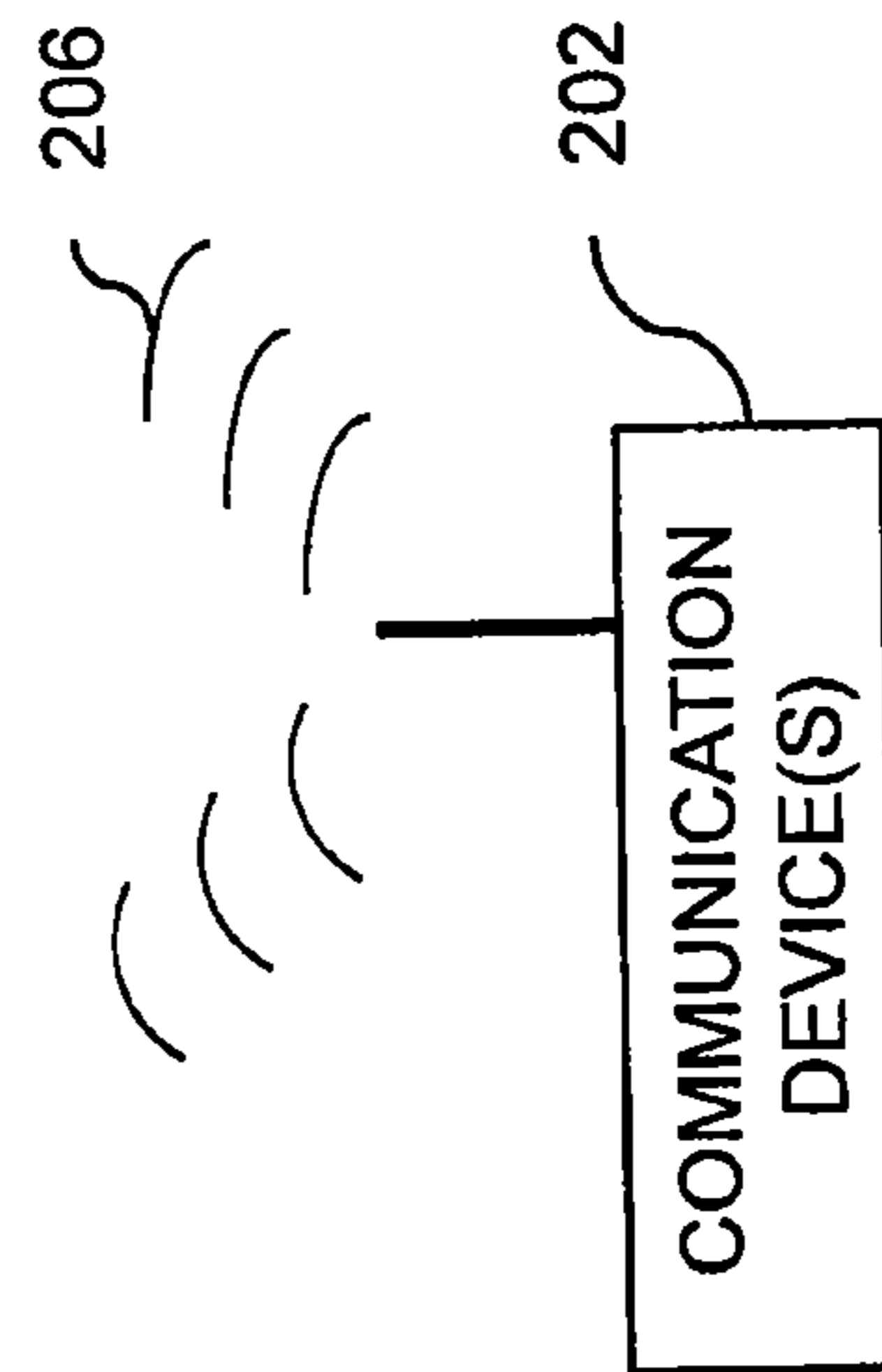
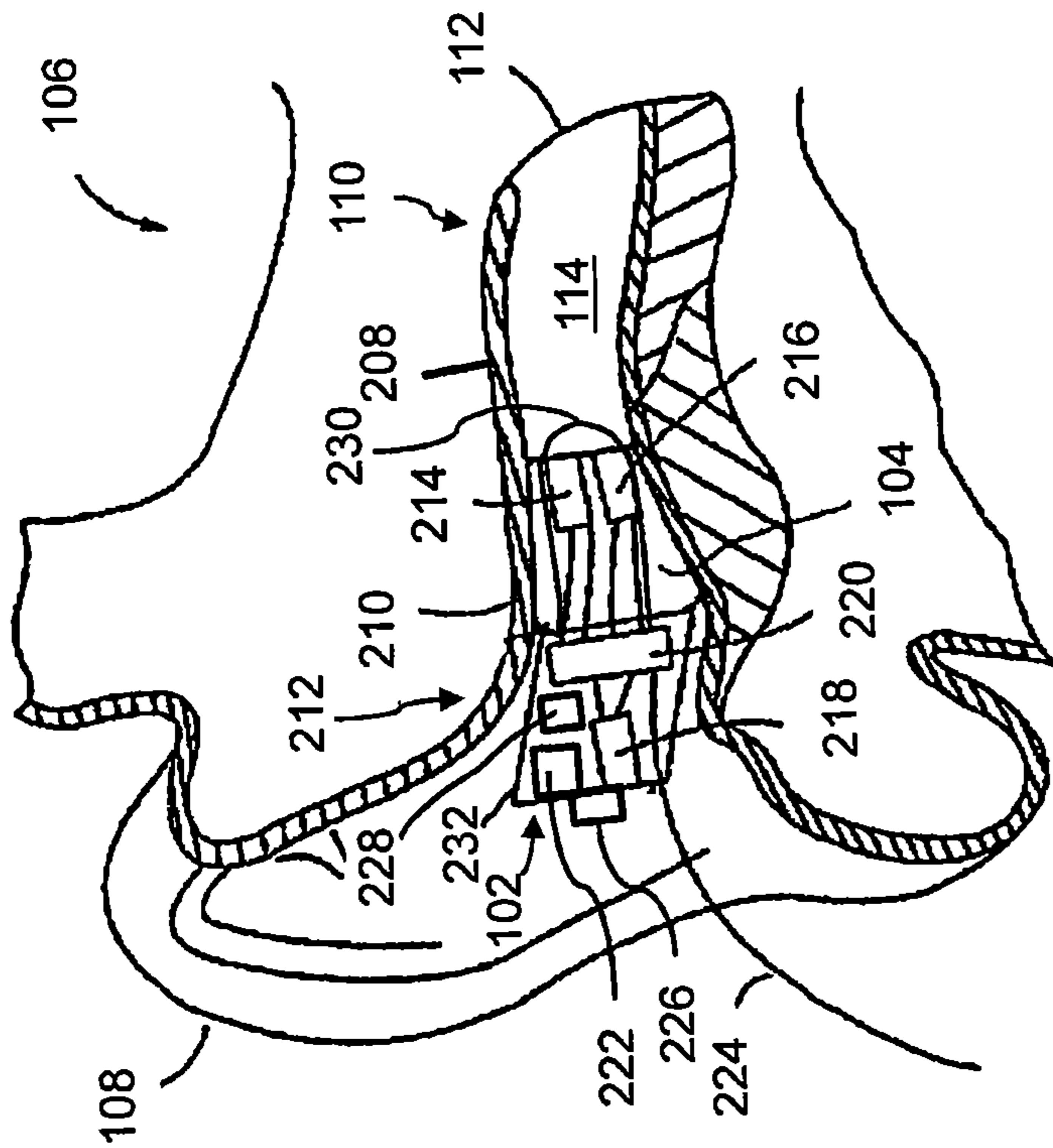


FIG. 2

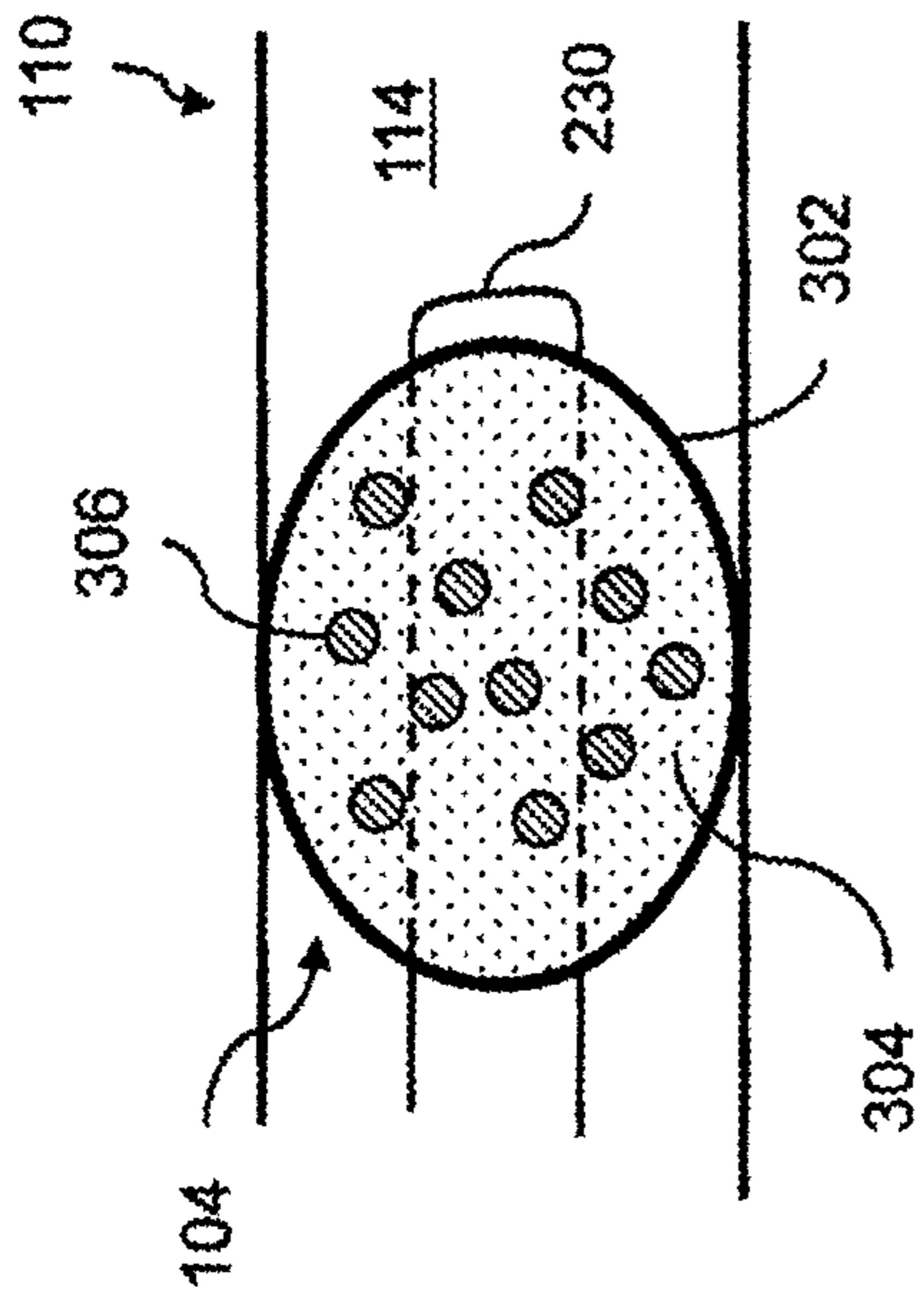


FIG. 3A

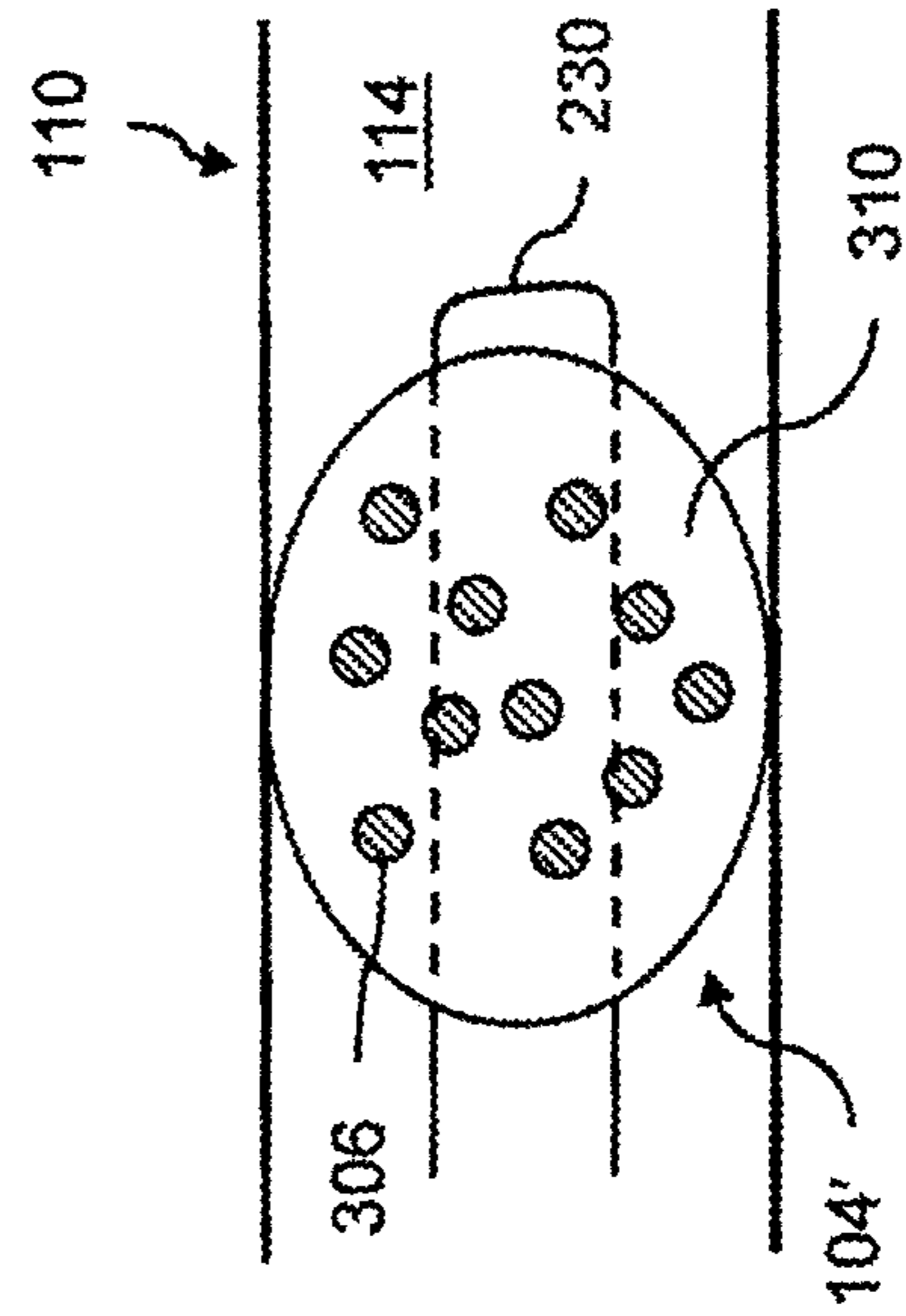


FIG. 3B

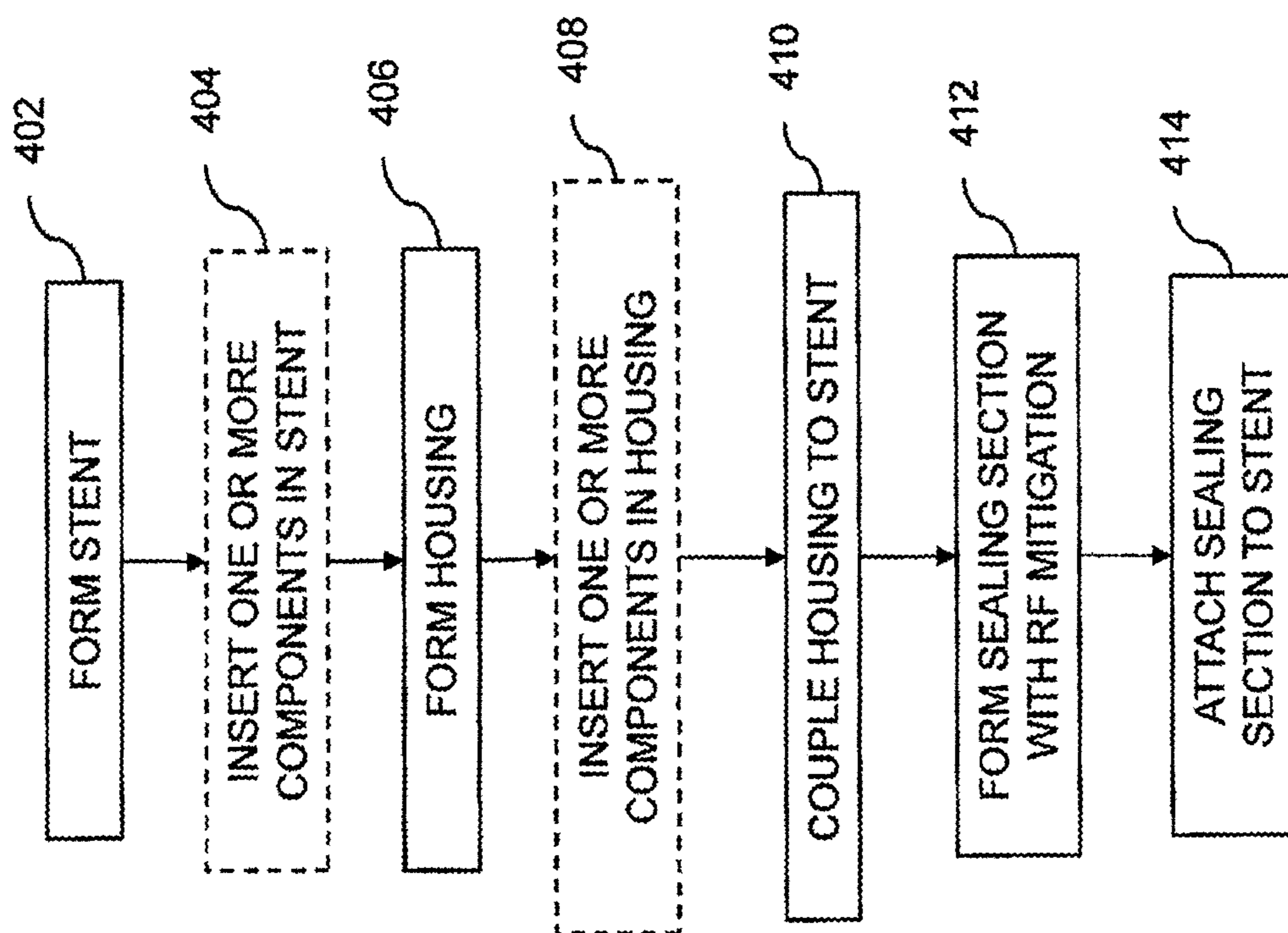


FIG. 4

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METHODS AND DEVICES FOR RADIO FREQUENCY (RF) MITIGATION PROXIMATE THE EAR

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application is a continuation of U.S. patent application Ser. No. 13/486,514, filed Jun. 1, 2012, which claims the benefit of U.S. Provisional Application No. 61/492,193 filed on Jun. 1, 2011, all of which are herein incorporated by reference in their entireties.

FIELD OF THE INVENTION

The present invention relates to earpieces and, more particularly, to earpieces and methods of forming earpieces for radio frequency (RF) mitigation proximate the ear.

BACKGROUND

During data transmission, communication devices (such as mobile phones) may emit radio frequency (RF) waves, a form of electromagnetic radiation. There are generally two types of electromagnetic radiation, ionizing and non-ionizing radiation. It is known that large doses of ionizing radiation (for example, X-rays, ultraviolet (UV) rays, and gamma rays) may cause cancer. There is concern that non-ionizing radiation (for example, visible light, microwaves and RF waves) may also cause cancer. Recent studies have indicated that there may be a link between the non-ionizing radiation (such as the radiation emitted from mobile phones) and cancer.

SUMMARY OF THE INVENTION

The present invention relates to an earpiece configured to be inserted in an ear canal. The earpiece includes an insertion element and a sealing section disposed on the insertion element and configured to conform to the ear canal. The sealing section is configured to substantially mitigate RF transmission and to substantially isolate the ear canal from an ambient environment.

The present invention also relates to an earpiece configured to be inserted in an ear canal of an ear. The earpiece includes a stent, a housing coupled to the stent and a sealing section disposed on the stent and configured to conform to the ear canal. The sealing section is configured to substantially mitigate RF transmission from a communication device proximate the ear and to substantially isolate the ear canal from an ambient environment.

The present invention also relates to methods of forming an earpiece. The method includes forming an insertion element, forming a sealing section to substantially mitigate RF transmission and attaching the sealing section to the insertion element. The sealing section is configured to conform to an ear canal and to substantially isolate the ear canal from an ambient environment.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be understood from the following detailed description when read in connection with the accompanying drawing. It is emphasized, according to common practice, that various features of the drawing may not be drawn to scale. On the contrary, the dimensions of the various features may be arbitrarily expanded or reduced for

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clarity. Moreover, in the drawing, common numerical references are used to represent like features. Included in the drawing are the following figures:

FIG. 1 is a side-view diagram of an exemplary earpiece inserted in an ear, according to an embodiment of the present invention;

FIG. 2 is a cross-section diagram of the earpiece shown in FIG. 1 which may receive RF radiation, illustrating one or more components that may be included in the earpiece, according to an exemplary embodiment of the present invention;

FIGS. 3A and 3B are cross-section diagrams of exemplary sealing sections, according to embodiments of the present invention; and

FIG. 4 is a flowchart diagram of an exemplary method of forming an earpiece for RF mitigation proximate the ear, according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Aspects of the present invention relate to earpieces and methods of forming earpieces for RF mitigation proximate the ear. An exemplary earpiece may include an insertion element and a sealing section disposed on the insertion element. The sealing section is configured to be inserted in an ear canal and may be configured to conform to the ear canal. According to an exemplary embodiment, the sealing section may be configured to substantially absorb RF radiation. According to another embodiment, the insertion element may also be configured to substantially absorb RF radiation. Accordingly, the earpiece may absorb RF emission and provide sound isolation from an ambient environment. According to an exemplary embodiment, the sealing section may include an expandable element filled with a medium and particles configured to absorb the RF emission. According to another exemplary embodiment, the sealing section may include a sealing material and particles configured to absorb the RF emission.

According to an exemplary embodiment, an exemplary earpiece may include at least one transducer. A transducer may be configured to receive a sound signal from a communication device coupled to the earpiece and to transmit the sound signal to the ear canal. The communication device may emit RF radiation. Accordingly, exemplary earpieces of the present invention may be coupled to one or more communication devices and may provide acoustic signals to the ear canal, while providing RF mitigation to the ear canal from RF radiation emitted by the communication device.

Referring to FIG. 1, a side-view diagram of an exemplary earpiece **100** is shown. Earpiece **100** is shown relative to ear **106** of user **118**. FIG. 1 also illustrates a general physiology of ear **106**. An external portion of ear **106** includes pinna **108**. An internal portion of ear **106** includes ear canal **110** and tympanic membrane **112** (i.e., an eardrum).

Pinna **108** is a cartilaginous region of ear **106** that focuses acoustic information from ambient environment **116** to ear canal **110**. In general, sound enters ear canal **110** and is subsequently received by tympanic membrane **112**. Acoustic information resident in ear canal **110** vibrates tympanic membrane **112**. The vibration is converted to a signal (corresponding to the acoustic information) that is provided to an auditory nerve (not shown).

Earpiece **100** may include insertion element **102** operatively coupled to sealing section **104**. Earpiece **100** may be configured to be inserted into ear canal **110**, such that sealing section **104** forms sealed volume **114** (also referred to herein

as sealed cavity 114) between sealing section 104 and tympanic membrane 112. Sealing section 104 may be configured to seal ear canal 110 from sound (i.e., provide sound isolation from ambient environment 116 external to ear canal 110).

As described further below, sealing section 104 may be configured to substantially absorb RF radiation 206 (FIG. 2) (i.e., RF transmission) emitted from communication device 202 (FIG. 2). Insertion element 102 may also be configured to substantially absorb RF emission.

Referring next to FIG. 2, a cross-section diagram of earpiece 100 in ear 106 is shown. FIG. 2 illustrates one or more components which may be included in earpiece 100. In general, earpiece 100 may be configured to be inserted into ear canal 110, and to form an acoustic seal (via sealing section 104) with walls 208 of ear canal 110 at a location 210 between entrance 212 to ear canal 110 and tympanic membrane 112.

FIG. 2 also illustrates communication device 202 proximate to ear 106. Although one communication device 202 is shown, it is understood that there may more than one communication device 202 which may be proximate to ear 106. In general, communication device 202 may emit (i.e., transmit) RF radiation 206 which may reach ear 106. Communication device 202 may include, for example, a mobile phone or a digital wireless system such as a data communication network. In general, communication device 202 may include any device that may emit RF radiation 206.

Sealing section 104 is described further below with respect to FIGS. 3A and 3B. In general, sealing section 104 may be configured to interfere with, absorb and/or reflect RF radiation 206 (i.e., to provide RF mitigation of RF radiation 206).

Insertion element 102 may be formed from, for example, thermoplastic elastomer (TPE) materials, materials having an elastomeric property (such as silicone), or other malleable materials capable of conforming to the ear canal. According to an exemplary embodiment, insertion element 102 may also be configured to provide mitigation of RF radiation 206. For example, insertion element 102 may be impregnated with an RF damping material such as a TPE filled with graphite and/or nickel powder. In general, RF mitigation components in earpiece 100 (in sealing section 104 and/or in insertion element 102) may be electrically coupled and/or grounded to user 118 or an alternate acceptable location.

Insertion element 102 may include stent 230 and housing 232. Stent 230 and/or housing 232 may include one or more components of earpiece 100, described further below. Sealing section 104 may be disposed on stent 230, such that stent 230 is also inserted in ear canal 110. Housing 232 may be coupled to stent 230 and may be placed at entrance 212 to ear canal 110. According to an exemplary embodiment, at least one of stent 230 or housing 232 may be configured to provide mitigation of RF radiation 206. In FIG. 2, earpiece 100 is illustrated as being disposed in ear 106. It is understood that various components of earpiece 100 may also be configured to be placed behind ear 106 or may be placed partially behind ear 100 and partially in ear 100.

According to an exemplary embodiment, earpiece 100 may be configured to communicate with communication device 202. According to another embodiment, earpiece 100 may be configured as a sound isolation device (described further below) and thus, may not be configured to communicate with communication device 202.

As shown in FIG. 2, insertion element 102 may include one or more components, such as electro-acoustical components, electrical components and/or pumping mechanism

228 for sealing section 104. Several example embodiments of components that may be included in insertion element 102 are discussed below.

According to one embodiment, earpiece 100 may include insertion element 102 and sealing section 104, without any electro-acoustic elements. In this embodiment, earpiece 100 may be configured simply as a sound isolation device, where sealing section 104 and/or insertion element 102 are configured to substantially mitigate RF radiation 206 from communication device 202. In this manner, RF radiation 206 may be substantially mitigated and/or prevented from reaching closed cavity 114 of ear canal 110. If sealing section 104 is configured to be expanded (such as described with respect to FIG. 3A), housing 232 may include pumping mechanism 228 to provide medium 304 (FIG. 3A) to sealing section 104 via stent 230.

According to another embodiment, earpiece 100 may include one or more electro-acoustical components (i.e., transducers). For example, stent 230 may include ear canal receiver (ECR) 214 (i.e., a loudspeaker). ECR 214 may be configured to provide acoustic content to sealed volume 114. ECR 214 may receive the acoustic content from communication device 202 or any other device capable of providing acoustic content (such as a portable audio player).

As a result of the seal provided by sealing section 104, ECR 214 may be able to generate a full range bass response time when reproducing sounds for user 118 (FIG. 1). The seal (by sealing section 104) may also significantly reduce a sound pressure level at tympanic membrane 112 resulting from the sound field at entrance 212 to ear canal 110 (to provide sound isolation).

According to another exemplary embodiment, stent 230 may include ear canal microphone (ECM) 216 located adjacent to ECR 214, which may also be acoustically coupled to sealed cavity 114. ECM 216 may measure a sound pressure level in sealed cavity 114. For example, the sound pressure level in sealed cavity 114 may be measured as a part of testing a hearing acuity of user 118 (FIG. 1). The sound pressure level in sealed cavity 114 may also be used to confirm an integrity of the acoustic seal of sealing section 104, as well as the working conditions of ECM 216 and ECR 214.

According to another exemplary embodiment, housing 232 may include ambient sound microphone (ASM 218). ASM 218 may monitor a sound pressure at entrance 212 to (occluded) ear canal 110. The sound pressure monitored by ASM 218 may be used, for example, to adjust the sound isolation provided by sealing section 104. As another example, the sound pressure monitored by ASM 218 may be used to adjust a volume of the audio content provided by ECR 214 to closed cavity 114.

All transducers (such as ECR 214, ECM 216 and ASM 218) may respectively receive or transmit audio signals to control circuit 220 in housing 232. Control circuit 220 may undertake at least a portion of the audio signal processing described above. Control circuit 220 may include, for example, a logic circuit, a digital signal processor or a microprocessor. Although not shown, earpiece 100 may also include a memory to store one or more signals from ECR 214, ECM 216 and ASM 218. As another example, earpiece 100 may be coupled to a memory that is remote from earpiece 100. The memory may include, for example, a random access memory (RAM), a magnetic disk, an optical disk, flash memory or a hard drive. Although ECR 214 and ECM 216 are shown in FIG. 2 as being in stent 230, it is understood that one or more of ECR 214 and ECM 216 may

be formed in housing 232 and coupled to closed cavity 114 via acoustic channels formed in stent 230.

Housing 232 may also include communication circuit 222 coupled to control circuit 220. In general, communication circuit 222 may be configured to receive and/or transmit signals to earpiece 100. Communication circuit 222 may be configured to communicate with communication device 202 via communication path 224. Communication path 224 may include a wired or wireless connection. It is understood that any transceivers (not shown) of communication circuit 222 may be positioned on housing 232 such that they are out of range of the RF mitigation provided by sealing section 104 and/or insertion element 102, such that the RF mitigation provided by earpiece 100 may not interfere with data transmission and/or reception by communication circuit 222.

According to another exemplary embodiment, housing 232 may include user interface 226. Housing 232 may also include pumping mechanism 228 for controlling expansion of sealing section 104. User interface 226 may be configured to control one or more of ECR 214, ECM 216, ASM 218, control circuit 220, communication circuit 222 and pumping mechanism 228. ECR 214, ECM 216, ASM 218, control circuit 220, communication circuit 222, user interface 226 and pumping mechanism 228 may be coupled together via a data and control bus (not shown). It is understood that earpiece 100 may include additional components (not shown) such as a battery.

Referring next to FIGS. 3A and 3B, exemplary sealing sections 104, 104' are shown. In particular, FIG. 3A is a cross-section diagram of sealing section 104 including expandable element 302 (such as a balloon) filled with medium 304; and FIG. 3B is a cross-section diagram of sealing section 104' in ear canal 110 including sealing material 310. Each of sealing section 104 and sealing section 104' may include particles 306 to substantially absorb RF radiation 206 (FIG. 2) (for example, between about 3 kHz to about 300 GHz).

Referring to FIG. 3A, sealing section 104 may include expandable element 302 filled with medium 304 mixed with particles 306 (for example, suspended in solution). Sealing section 104 is configured to substantially attenuate sound from ambient environment 116 (FIG. 1). Sealing section 104 is also configured to substantially absorb RF radiation 206 (FIG. 2) via particles 306. In general, particles 306 may be configured to interfere with, absorb and/or reflect RF radiation 206 (FIG. 2).

Expandable element 302 may include balloons of various shapes, sizes and materials, for example constant volume balloons (low elasticity $\leq 50\%$ elongation under pressure or stress) and variable volume (high elasticity $> 50\%$ elongation under pressure or stress) balloons. Pumping mechanism 228 (FIG. 2) may be used to provide medium 304 to expandable element 302.

Expandable element 302 may be formed from any compliant material that has a low permeability to medium 304. Examples of materials of expandable element 302 include any suitable elastomeric material, such as, without being limited to, silicone, rubber (including synthetic rubber) and polyurethane elastomers (such as Pellethane® and Santoprene™).

Materials of expandable element 302 may be used in combination with a barrier layer (for example, a barrier film such as SARANEX™), to reduce the permeability of expandable element 302. In general, expandable element 302 may be formed from any suitable material having a range of Shore A hardness between about 5 A and about 90

A, with an elongation of about 500% or greater. Expandable element 302 may also be made of RF absorbing elastomers such as a polyurethane filled with electrically conductive material such as iron graphite and/or nickel particles.

Medium 304 may include, without being limited to, electrically conductive liquids such as saline and colloidal liquids that have carrier fluids including, for example, fluorocarbon liquids such as Fluorinert™ (manufactured by 3M™) (including, for example, FC-770), ethylene glycol and isopropyl alcohol (with particles 306 suspended in solution).

Medium 304 may include any suitable liquid or gel capable of expanding and contracting expandable element 302 and that would maintain a comfortable level of pressure for user 118 (FIG. 1) of earpiece 100. In general, examples of medium 304 include, without being limited to, silicone, non or low permeable-based polymers, gels, fluorocarbon liquids, ethylene glycol, isopropyl alcohol or saline.

Particles 306 may include ferromagnetic particles, ferromagnetic particles or electrically conductive particles such as graphite, nickel, and/or iron. As understood by one of skill in the art, particles 306 may be formed large enough to provide adequate radio frequency interference (RFI) shielding and may be formed small enough to not impede a mechanical operation of earpiece 100 (FIG. 1). In an exemplary embodiment, a size of particles 306 may range from about 0.1 μm to about 100 μm in diameter. In general, particles 306 may include any suitable particles configured to interfere with, absorb and/or reflect RF radiation 206 (FIG. 2). Although particles 306 are described herein, it is understood that medium may include fibers instead of or in addition to particles 306. The fibers may also be formed of ferromagnetic material, ferrimagnetic material or electrically conductive material, as described above with respect to particles 306.

As shown in FIG. 3B, sealing section 104' is similar to sealing section 104 (FIG. 3A), except that sealing section 104' includes sealing material 310 having embedded particles 306 for substantially mitigating RF radiation 206 (FIG. 2). Thus, sealing section 104' may also be configured to seal ear canal 110 from ambient sound 116 (FIG. 1).

Sealing material 310 may include, without being limited to, foam, rubber or any suitable sealing material capable of conforming to ear canal 110 and for sealing ear canal 110 to provide sound isolation. Sealing material 310 may also be composed of RF damping materials such as a polyurethane and or any other applicable polymer or rubber such as silicone filled with RF shielding materials such as nickel, graphite, and/or iron particles.

In general, earpiece 100 (FIG. 1) may provide RF shielding by using any suitable electrically conductive material. Because metals are typically not flexible and may be difficult form into a suitable earpiece shape (such as by injection molding), in an exemplary embodiment, conductive particles/fibers may be used as fillers to make polymers conductive (and thus to provide effective RF shielding materials).

According to another exemplary embodiment, at least one of insertion element 102 or sealing section 104 may be formed from a flexible material that is inherently conductive, without using fillers (such as conductive particles and/or fibers). For example, a metal earpiece body may be formed. An example of this is provided with respect to the medium 304 (FIG. 3A) used to fill expandable element 302. If a fluid is conductive, it may be capable of provide RF shielding without fillers such as particles and/or fibers. However, based on the desired shielding characteristics (i.e.,

a frequency range of RF radiation and a desired reflectivity), fillers may be added to improve conductivity and thus, RF shielding. For example, the higher the conductivity and the thicker the material, the greater the shielding capability by the material, and the greater the shielding at lower frequencies. As is the case with solids, shielding ability may be afforded to nonconductive fluids by using conductive fillers.

Referring back to FIG. 2, although earpiece 100 is described above as being configured to mitigate RF radiation 206 from communication device 202, earpiece 100 may also be configured to mitigate RF radiation produced by earpiece 100 itself. For example, insertion element 102 and/or sealing section 104 may mitigate RF radiation emitted by communication circuit 222. In an exemplary embodiment, earpiece 100 may be configured to absorb between about 70% and about 100% of generated and/or received RF radiation within a frequency range of communication device 202 and internally generated radiation typically in a range between about 3 kHz and 300 GHz.

Referring next to FIG. 4, a flowchart diagram of an exemplary method for forming an earpiece capable of RF mitigation is shown. The steps illustrated in FIG. 4 represent an example embodiment of the present invention. It is understood that certain steps may be performed in an order different from what is shown. It is also understood that certain steps may be eliminated.

At step 402, stent 230 (FIG. 2) is formed, for example, via injection molding. According to an exemplary embodiment, stent 230 (FIG. 2) may be formed with a material capable of RF mitigation. For example, stent 230 (FIG. 2) may be formed of an RF damping material such as polyurethane filled with RF shielding material such as iron, nickel and/or graphite particles. As another example, stent 230 (FIG. 2) may be formed of a material with embedded ferromagnetic particles, ferrimagnetic or electrically conductive particles for RF mitigation.

At optional step 404, one or more components may be inserted in stent 230 (FIG. 2). For example, as shown in FIG. 2, one or more electro-acoustic components (such as ECR 214 and/or ECM 216) may be formed in stent 230.

At step 406, housing 232 (FIG. 2) may be formed, for example, via injection molding. According to an exemplary embodiment, housing 232 (FIG. 2) may be formed with a material capable of RF mitigation. For example, housing 232 (FIG. 2) may be formed of an RF damping material such as polyurethane filled with RF shielding material such as iron, nickel, and/or graphite particles. As another example, housing 232 (FIG. 2) may be formed of a material with embedded ferromagnetic particles, ferrimagnetic or electrically conductive particles for RF mitigation.

At optional step 408, one or more components may be inserted in housing 232 (FIG. 2). For example, as shown in FIG. 2, electro-acoustic components (such as ASM 218), electrical components (such as control circuit 220, communication circuit 222 and/or user interface 226) and/or other components (such as pumping mechanism 228) may be formed in housing 232. At step 410, housing 232 (FIG. 2) is coupled to stent 230.

At step 412, sealing section 104 (FIG. 1) is formed such that it includes RF mitigation properties. For example, sealing section 104 may include medium 304 (FIG. 3A) and particles 306 for RF mitigation or may include sealing material 310 (FIG. 3B) with embedded particles 306 for RF mitigation. Sealing material 310 (FIG. 3B) may also be formed of RF damping material such as polyurethane filled with RF shielding materials such as iron, nickel and/or graphite particles.

At step 414, sealing section 104 (FIG. 2) is attached to stent 230. Sealing section 104 (FIG. 2) may be attached to stent 230 via any suitable attachment method, such as, but not limited to, bonding, adherence with an adhesive, thermal bonding, molding and ultrasonic bonding.

Although the invention is illustrated and described herein with reference to specific embodiments, the invention is not intended to be limited to the details shown. Rather, various modifications may be made in the details within the scope and range of equivalents of the claims and without departing from the invention.

We claim:

1. An earpiece, comprising:

a pump; and

a sealing section configured to conform to an ear canal, wherein the pump is configured to provide a mixture to an expandable element of the sealing section disposed on a stent of the earpiece so as to expand the expandable element and cause the sealing section to conform to the ear canal, wherein the expandable element includes:

a first layer, wherein the first layer is an elastic layer with a Shore A value between about 5 to 40; and
a barrier layer, where the barrier layer is less permeable to the mixture than the first layer.

2. The earpiece of claim 1, further comprising an insertion element.

3. The earpiece of claim 2, wherein the sealing section is disposed on the insertion element.

4. The earpiece of claim 1, wherein the sealing section is configured to mitigate radio transmission.

5. The earpiece of claim 1, wherein the sealing section is configured to isolate the ear canal from an ambient environment.

6. The earpiece of claim 1, further comprising an ear canal receiver configured to provide acoustic content to a sealed volume between the sealing section and a tympanic membrane.

7. The earpiece of claim 6, wherein the ear canal receiver is configured to generate a full range bass response time when reproducing a sound.

8. The earpiece of claim 1, further comprising an ear canal microphone configured to measure a sound pressure level in a sealed volume between the sealing section and a tympanic membrane.

9. The earpiece of claim 1, further comprising an ambient sound microphone configured to monitor a sound pressure at an entrance of the ear canal.

10. The earpiece of claim 1, further comprising a user interface configured to control an ear canal microphone, an ear canal receiver, an ambient sound microphone, a control circuit, a communication circuit, the pump, or a combination thereof.

11. The earpiece of claim 1, wherein the sealing section includes a plurality of particles configured to interfere with a radio frequency transmission, absorb the radio frequency transmission, reflect the radio frequency transmission, or a combination thereof.

12. A method of forming an earpiece, comprising:

attaching a sealing section to an insertion element of the earpiece; and

attaching a pump to a channel, where the channel is connected to an expandable element, wherein the pump is configured to provide a mixture to the expandable element of the sealing section disposed on a stent of the earpiece so as to expand the expandable element and

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cause the sealing section to conform to the ear canal, wherein the expandable element includes:

a first layer, wherein the first layer is an elastic layer with a Shore A value between about 5 to 40; and
 a barrier layer, where the barrier layer is less permeable to the mixture than the first layer.

13. The method of claim **12**, further comprising forming an insertion element of the earpiece.

14. The method of claim **12**, further comprising forming the sealing section prior to attaching the sealing section to the insertion element.

15. The method of claim **12**, further comprising forming a stent of the earpiece.

16. The method of claim **15**, further comprising inserting an ear canal receiver, an ear canal microphone, or a combination thereof, into the stent.

17. The method of claim **12**, further comprising a housing of the earpiece.

18. The method of claim **17**, further comprising inserting an ambient sound microphone, a control circuit, a user interface, or a combination thereof, into the housing of the earpiece.

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19. The method of claim **12**, further comprising incorporating a medium into the sealing section for a radio frequency mitigation.

20. An earpiece, comprising:

a stent;

a housing coupled to the stent; and

a sealing section configured to conform to an ear canal,

wherein a pump is configured to provide a mixture to an expandable element of the sealing section disposed on the stent of the earpiece so as to expand the expandable element and cause the sealing section to conform to the ear canal, wherein the expandable element includes:

a first layer, wherein the first layer is an elastic layer with a Shore A value between about 5 to 40; and

a barrier layer, where the barrier layer is less permeable to the mixture than the first layer.

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